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The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) is conducting a research program with the goal of using virtual environments (VE) to train dismounted soldiers. To accomplish this goal, the conditions necessary for transfer of training from VE to real-world environments must be identified. This paper describes an experiment in which a VE computer model of a large office building is used to train spatial knowledge as it relates to learning routes through that building. This task is especially relevant to mission rehearsal of a hostage rescue attempt or other missions performed by Special Operations forces.

Sixty college students studied directions and photographs of landmarks for a complex route, then rehearsed the route using either the VE model, the actual building, or verbal directions and photographs. Everyone was then tested in the actual building. Building-trained students made fewer wrong turns than did VE-trained students, who in turn made fewer wrong turns and took less time to traverse the route than did verbally trained students. The results indicate that individuals can learn how to navigate through real-world places by training in a virtual environment.

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Bob G. Witmer, John H. Bailey, and Bruce W. Knerr
U.S. Army Research Institute

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Technical Report 1022

Training Dismounted Soldiers in Virtual Environments: Route Learning and Transfer

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FOREWORD

The U.S. Army has made a substantial commitment to Distributed Interactive Simulation (DIS) and to the electronic battlefield for combat training. The current generation DIS training system, Simulation Networking (SIMNET), and next-generation system, the Close Combat Tactical Trainer (CCTT), provide a realistic combat simulation for soldiers fighting from vehicles, but not for individual dismounted soldiers. Virtual Environment (VE) technology has the potential to provide that capability. The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI), with contract support from the University of Central Florida Institute for Simulation and Training, has embarked on a research program to investigate the use of VE for training dismounted soldiers.

This report describes the third in a series of experiments designed to explore the potential of virtual environments for training dismounted soldiers. The research employs a highly detailed computer model of a large office building to determine if visual immersion in a virtual world improves route and configuration knowledge in the real world. It discusses which elements of a virtual environment are important for learning spatial knowledge, and reveals some interesting relationships between the sense of presence, simulator sickness, and task performance.

The U.S. Army Research Institute for the Behavioral and Social Sciences Simulator Systems Research Unit conducts research to improve the effectiveness of training simulators and simulations. The work described is part of the ARI research task entitled "VIRTUE—Virtual Environments for Combat Training and Mission Rehearsal."

EDGAR M. JOHNSON
Director

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This technical report would not have been possible without the assistance of some very creative people. Kudos go to Kimberly Abel, Mike Goslin, Greg Wiatroski, and Trenton Tuggle at the Institute for Simulation and Training for their tireless efforts in developing the virtual building model—one of the largest virtual environments created to date. We also would like to thank John Gildea and Dan McDonald for their help in data collection and data reduction.

TRAINING DISMOUNTED SOLDIERS IN VIRTUAL ENVIRONMENTS: ROUTE LEARNING AND TRANSFER

EXECUTIVE SUMMARY

Requirement:

The U.S. Army has invested heavily in the use of Distributed Interactive Simulation (DIS) technology for providing training realism in collective and combined arms training. Current and next-generation DIS systems provide effective training for soldiers fighting from vehicles, but do not do the same for dismounted soldiers. Virtual environment (VE) technology offers the opportunity to involve the dismounted soldier in the combat training provided by DIS. It could provide not only the means to train dismounted soldiers, but also could result in more realistic combined arms training, in which the contributions of dismounted soldiers to the battle outcome are accurately represented. However, there is no indication of how well skills acquired in VE transfer to the real world. The purpose of this experiment was to obtain such evidence.

Procedure:

A highly detailed model of a large office building was constructed using Multigen and WorldToolKit. The model was rendered using a Silicon Graphics Crimson Reality Engine and displayed via a Fakespace Lab two-color Boom2. The Boom2 consists of a high resolution binocular display on the end of an arm that allows six degree-of-freedom movement and thumb buttons that control forward and backward motion. This set-up allows travelers to actively explore building landmarks, routes, and configurations much as they would in the real world.

The participants were sixty college students who had no previous exposure to the building. Subjects first studied route directions and photographs of landmarks, either with or without a map, then were assigned to one of three rehearsal groups. These were (1) a VE group that rehearsed in the building model, (2) a building rehearsal group that rehearsed in the actual building, and (3) a symbolic rehearsal group that relied on verbal rehearsal of the route directions. Route knowledge was assessed by testing participants for transfer of training in the actual building. Building configuration knowledge was tested by having participants complete a projective convergence test, where they were required to

estimate the distance and direction to selected landmarks, and by measuring the capability of subjects to exit the building quickly using an unrehearsed route.

Findings:

The major research objective of this project was to assess differences in transfer task performance as a function of the medium used in rehearsing the task (group effect). Subjects who rehearsed in the building made fewer wrong turns than did subjects who rehearsed in the virtual environment (VE). VE subjects, in turn, made fewer wrong turns and took less time to traverse the route than did subjects who rehearsed symbolically. Each of these differences was statistically significant. The results suggest that individuals can learn how to navigate through real-world places by training in a virtual environment.

In practicing the route, subjects might be expected to accrue knowledge about the building layout or configuration. However, there were no significant differences in configuration knowledge among the various rehearsal conditions and no significant differences as a function of map use. Only the effect of gender was significant, with males performing better than females. No significant interactions were found.

Utilization of Findings:

We have demonstrated that spatial skills learned in a virtual environment transfer to real-world settings if the virtual environment adequately represents important landmarks and other stimulus cues. This has potential military applications in which knowledge of interior spaces is important (e.g., hostage rescue mission rehearsal). But more important, it demonstrates that the virtual environment is a potentially effective training medium. While the building model used in this experiment was not quite as effective in training subjects as the actual building, it was much better than verbally rehearsing route directions, even for participants who had previously studied a map.

TRAINING DISMOUNTED SOLDIERS IN VIRTUAL ENVIRONMENTS: ROUTE LEARNING AND TRANSFER

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Training Dismounted Soldiers in Virtual Environments: Route Learning and Transfer

In a recent movie, virtual environments (VE) were portrayed as presenting information in a way that resulted in very rapid knowledge acquisition. The VE was so effective that a character in the movie was transformed from a simpleton to a genius in a matter of months. In reality, there is no evidence to suggest that learning occurs any more rapidly in a VE than it would in the real world. Knerr et al. (1994) have presented data that show that performance of psychomotor tasks trained in a VE improves with additional practice in that environment. While Regian, Monk, and Shebilske (1993) have provided some evidence that real world skills can be trained in a VE, Kozak, Hancock, Arthur and Chrysler (1993) were unable to demonstrate transfer from the VE to the real world. Regian et al. (1993) compared the effectiveness of using a 2-D "God's eye view" of a building for training configuration knowledge with a virtual reality representation of that same building. Tests of navigation in the real building tended to favor the 2-D representation, but the differences in the two training conditions were small. Regian et al., however, did not compare the effectiveness of virtual environments with a real world environment as a training medium. In addition, previous work has done little to identify the conditions that influence learning in a virtual environment.

The U.S. Army Research Institute has embarked on a research program to investigate the utility of virtual environments for training applications. The ultimate goal of the research is to demonstrate the use of virtual environments in training dismounted soldiers. To accomplish this goal it is important to establish that current virtual environments have the capability to train real world skills. In the broadest sense, the objectives of this research are to assess the extent to which knowledge acquired in virtual environments transfers to real world environments, and to determine the necessary conditions for transfer of training from virtual environments to real world environments. The specific objective of this research is to test the relative effectiveness of virtual environments for training spatial knowledge as it relates to wayfinding in large buildings. Specifically, how effective are virtual environments in conveying the information necessary for learning routes to a specified location within a large building? Also, how well does the virtual environment provide the information needed for acquiring knowledge about the building layout or floorplan (i.e., knowledge of the building configuration)? This research is especially relevant to mission rehearsal of a hostage rescue attempt or other missions performed by special operations forces.

Acquiring Spatial Knowledge

Much theorizing and considerable research have been done in order to

understand how humans acquire information regarding places and how they are able to find their way around cities and other complex environments. Nearly a half century ago, Tolman suggested that animals learned by using a tentative cognitive map. According to Tolman, " ....it is this tentative map, indicating routes and paths and environmental relationships, which finally determines what responses, if any, the animal will release" (Tolman, 1948, p. 192). Tolman's postulation of cognitive maps, though based on an intensive program of research, was controversial at the time and conflicted with the dominant stimulus-response theory. More recent work (Lynch,1960; Evans, 1980; Siegel 1981) has assumed the existence of these cognitive maps and concentrated instead on how they are acquired. Siegel and White (1975) use the term spatial representation to connote the knowledge structure that allows persons to find their way around their environment. They suggest that a person's knowledge of spaces generally begins with noticing and remembering landmarks. Landmarks are ".... the strategic foci to and from which one travels" and they help the traveler stay on course (Siegel & White, 1975). Routes linking the landmarks are formed while acting in the context of these landmarks. With sufficient experience in following routes an overall gestalt of a city, neighborhood or building may be formed. This gestalt consists of routes and landmarks interrelated in a networklike assembly. The form or structure of this assembly constitutes one's configuration knowledge. Hence, a learning hierarchy in which configuration learning succeeds and depends on route knowledge, and route learning succeeds and depends on recognizing landmarks, provides the basis for a model of how spatial representations are acquired. In the following paragraphs, additional information regarding landmark learning, route learning and configuration learning, and measures of each, will be discussed.

Learning Landmarks and Places

Landmarks are unique patterns of perceptual events at a specific geographic location. The intersection of Broadway and 42nd Street is as much a landmark as the Prudential Center in Boston or the Eiffel Tower in Paris. Landmark learning is primarily visual and may be based on a "recognition in context memory" (Siegel & White, 1975). Golledge (1991) states that landmark knowledge is the simplest level of knowledge that an individual can have regarding an environment. Lynch (1960) suggests that the number, type, and distinctiveness of landmarks in an environment can influence how well individuals can find their way from one place to another in that environment. Landmarks are more likely to be noticed and remembered if they are located at intersections, where motorists and pedestrians have more viewing time. Landmarks that contrast with their surrounding environment are also more likely to be noticed and remembered. For example, a small church among tall buildings or an old building among new constitute differences that will in all likelihood be noticed by the perceiver (Appleyard, 1969; Rapoport, 1977). Landmarks are often associated with the range of activities occurring within their boundaries (Canter, 1977). In buildings, furniture may serve

as markers for identifying places.

Learning Routes

Route knowledge consists of the procedural knowledge required to successfully traverse distances between origins and destinations (Golledge, 1991). It consists of explicit representation of points along the route where turns occur and the actions to be taken at each one. Implicitly, it also represents distances along each route segment, orientation cues, and ordering of landmarks (Goldin & Thorndyke, 1981). Route knowledge is to some extent sequence knowledge that is built around landmarks and other decision points. Routes may be learned by associating changes in bearing with landmarks at intersections or choice points (Siegel & White, 1975). Active movement through the environment seems to enhance route learning when compared to passive movement (Appleyard, 1976). What is remembered along the route may also be influenced by the mode of transportation (e.g., driving vs. walking) and by the speed of movement along the route (Rapoport, 1977). The difficulty of learning a route was shown to vary with the route length, the number of changes in route direction, and the number of route choices at each choice point (Best, 1969).

Active exploration of one's environment usually results in the acquisition of routes over a period of time. In some cases, however, routes may be learned more quickly with the aid of maps, written and verbal directions, or both. A map is a miniaturized simplification of reality, which requires the users to transform their normal eye-level viewpoint to the particular bird's eye view of the map (Canter, 1977). Maps typically use symbols to represent what may be found in any location.

Describing a route to a specified destination, Streeter, Vitello and Wonsiewicz (1985) found that taped verbal instructions were superior to a customized route map, a combination of verbal instructions and a customized map, and a standard road map. Drivers who received the verbal instructions drove to destinations in fewer miles, took less time and had 70% fewer errors than did the customized map drivers.

Learning Configurations

Configuration refers to the way in which spaces are related to one another, not only pairwise but also with respect to the overall pattern that they constitute (Peponis, Zimring, & Choi, 1990). Configurational knowledge represents the configural relations among locations and routes within an environment. This type of knowledge represents object locations and interobject distances with respect to a fixed frame of reference, as on a conventional map (Goldin & Thorndyke, 1981). Hence, configurational knowledge can be learned directly from a map (Evans &

Pezdek, 1980). Alternately, as knowledge of an environment accumulates and distance information becomes more precise with repeated direct experience with that environment, notions of angularity, direction, continuity and relation emerge (Golledge, 1991). Learning configurations during active interaction with the environment (i.e., via navigation) seems to produce different results than learning configurations with the aid of a map. With a moderate amount of navigation experience in an environment, 20 minutes of map learning was shown to be superior for making judgements of relative location and straight-line distances between objects (Thorndyke & Hayes-Roth, 1980). However, learning from navigation is superior for orienting oneself to unseen objects and for estimating route distances.

Measuring the Acquisition of Spatial Knowledge

Researchers have been very ingenious in developing measures of spatial knowledge. Landmark knowledge is usually assessed by asking observers to recognize or recall the landmarks that they have seen along a route (Pezdek & Evans, 1979; Evans, 1980). Route knowledge has been assessed by asking subjects for verbal recall (protocols) of their spatial experiences (Lynch, 1960), by measuring the number of errors made in traversing a route and the time to complete the route (Streeter et al., 1985), and by determining how many subjects got lost (Best, 1969). At least one study required subjects to sort photos of route segments and landmarks in the order that they appear along the route (Evans, Skorpanich, Garling, Bryant, & Bresolin, 1984). Another required that subjects estimate distances between scenes that appeared along the route (Subkoviak, 1975). Configuration knowledge has most often been measured by asking subjects to sketch a map of the area being learned (Lynch, 1960; Appleyard,1970). However, scoring these sketched maps is extremely difficult, and some researchers feel that these maps may underestimate how much configurational knowledge has been acquired (Siegel, 1981). As an alternative to producing drawings, Siegel (1981) has proposed that configurational knowledge be measured using the projective convergence technique. The technique requires subjects to estimate the bearing and distance to a number of landmarks (not in the line of sight) from three different sighting locations. The end points of lines representing the bearing and distance estimates form a triangle from which a number of measures can be derived.

Predicting Performance on Route Learning and Configurational Tasks

Various predictors of route learning and configurational knowledge have been investigated. These include gender, self-reported sense of direction, and various spatial ability tests. Evans (1980), after reviewing studies on spatial cognition in which gender differences were investigated, concluded that there is little evidence to support gender differences in the performance of real scale spatial tasks.

Kozlowski and Bryant (1977) showed that subjects who report having a good sense of direction perform significantly better on a task that requires them to point to an unseen location than do subjects who report having a poor sense of direction.

Virtual Environments and the Acquisition of Spatial Knowledge

Virtual environments (VE) are computer simulated surroundings with which users experience and interact using various interface devices. The best interface devices are simple, permit the user to interact directly with the environment, and do not require the user to learn new responses. Head-mounted displays allow users to change their viewpoint by moving their head. The Boom2 display used in this research allows users to move in the direction that they are looking. Movement in a VE may be controlled manually by pressing a control button (as with the Boom2), or a simple control device (e.g., joystick) may be used to determine movement direction and speed. More natural means of moving (e.g., a treadmill) have also been used. The user is sometimes represented in the VE as a figure but more commonly the user is represented only as an egocentric viewpoint. A common characteristic of a virtual environment is that users perceive that they are moving through it. It is this sense of movement that may be responsible for both a sense of presence and the simulator sickness reported by some users (Kennedy, Lane, Lilienthal, Berbaum, & Hettinger, 1992).

Virtual environments would seem to be the ideal media for conveying knowledge about landmarks, routes and configurations because like real world environments, a virtual environment allows people to become immersed in it and act in it and on it. Virtual environments also preserve the visual-spatial characteristics of the simulated environment (Regian, Shebilske, & Monk, 1992). For example, when observers turn their heads to the left in a VE, they see what is on their left. A VE can portray the same landmarks, routes and configurations that exist in the real world and allows travelers to actively explore these landmarks, routes and configurations much as they would in the real world. A VE, however, may be constructed to measure this exploration much more accurately and thoroughly than would be possible in a real world setting. For example, in a VE, it is a fairly simple matter to record the length of time a traveler's gaze was directed at a particular landmark, and how much time was spent at each decision point.

If the virtual environment allows observers to fly above the terrain or building, they may gain benefits similar to those gained by exposure to a map. Observers may also spot the destination or important landmarks from above, which may help them maintain their course toward the destination and prevent them from getting lost. The size of landmarks in virtual environments may be more critical than in the real world because the relatively low resolution of many VE display devices effectively reduces visual acuity. This makes it necessary to be close to

small objects in VE to positively identify them. Distinctive textures and visual patterns may not be as easily discriminable in the virtual environment for the same reason. The mode of locomotion in the virtual environment (e.g., joystick or other manual controller) may differ from the usual mode of locomotion in the real world (e.g., walking). Until the user becomes very proficient with the manual controller, it may impede the acquisition of landmark, route, or configuration knowledge.

Designing a Virtual Environment

The virtual environment used in this experiment was developed under our direction by the University of Central Florida Institute for Simulation and Training. The virtual environment consists of a computer model of the Research Pavilion, an office building (approximately 117,950 sq. ft.) located in the Central Florida Research Park. The model comprised all corridors and common spaces that were not parts of specific office areas on the first three floors of the building. It also included a suite of offices and work spaces on the third floor and a second smaller suite of offices and a classroom on the second floor. Floorplans of the areas modeled on each floor are included as Figures 1, 2 and 3. Only the unshaded areas on these figures were modeled in detail (roughly 18,000 sq.ft.).

Many of the furnishings (desks, file cabinets, bookcases) found in the offices and work spaces were included in the VE model of the building, as were prominent landmarks (e.g., pictures on the walls). Functional staircases were modeled as were outdoor areas in the immediate vicinity of the building. The model also included realistic out-the-window views of the parking areas and surrounding flora. Fine details of the building were modeled to include baseboards, fluorescent lights, signs indicating exits and stairwells, and room numbers. Areas of the building that were inaccessible for research purposes were shown as closed doors in the VE model, and are shown as shaded areas on Figures 1, 2, and 3. All doors, except those in inaccessible areas, automatically opened when the subject approached within 10 feet of the door and remained open for several seconds.

The authors developed written specifications that described the areas of the building to be modeled in great detail. Features of corridors and lobby areas were identified, described, and located. The furnishings for unique work areas and office spaces (e.g., reception area, classroom) were identified, described, and their position and orientation in the room was designated. Because most individual offices were similarly furnished, a general specification was used for these offices. The standard office furniture includes a desk with a chair, a computer table with a keyboard and monitor, a four-shelf bookcase, and a file cabinet. These written specifications were provided to the modelers to assure that they would not miss important building features in developing the virtual environment.

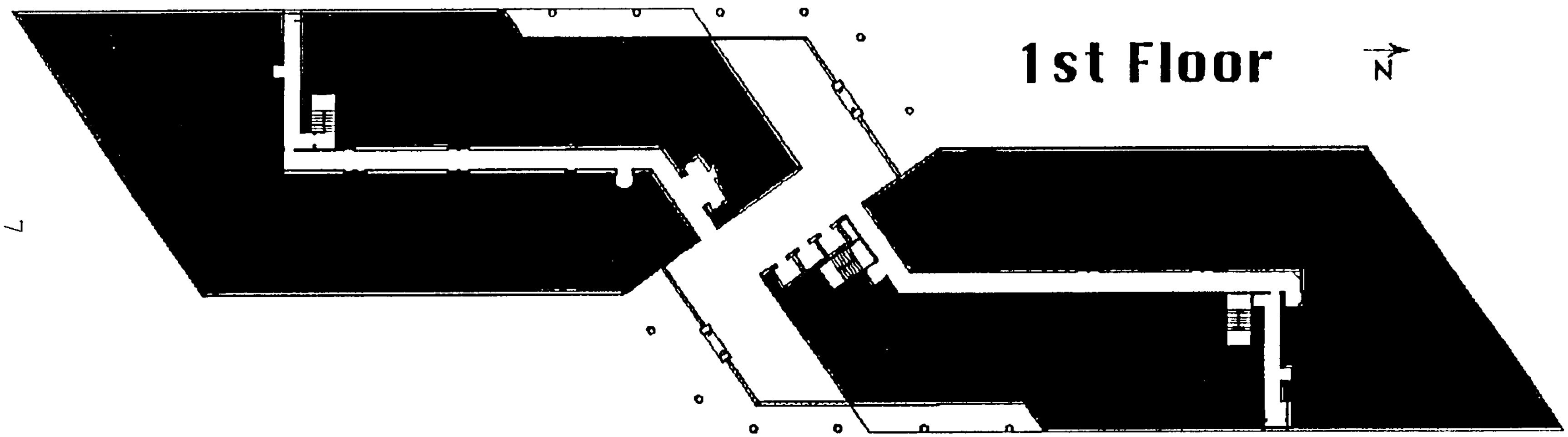

Figure 1. Areas of the Research Pavilion modeled—first floor.

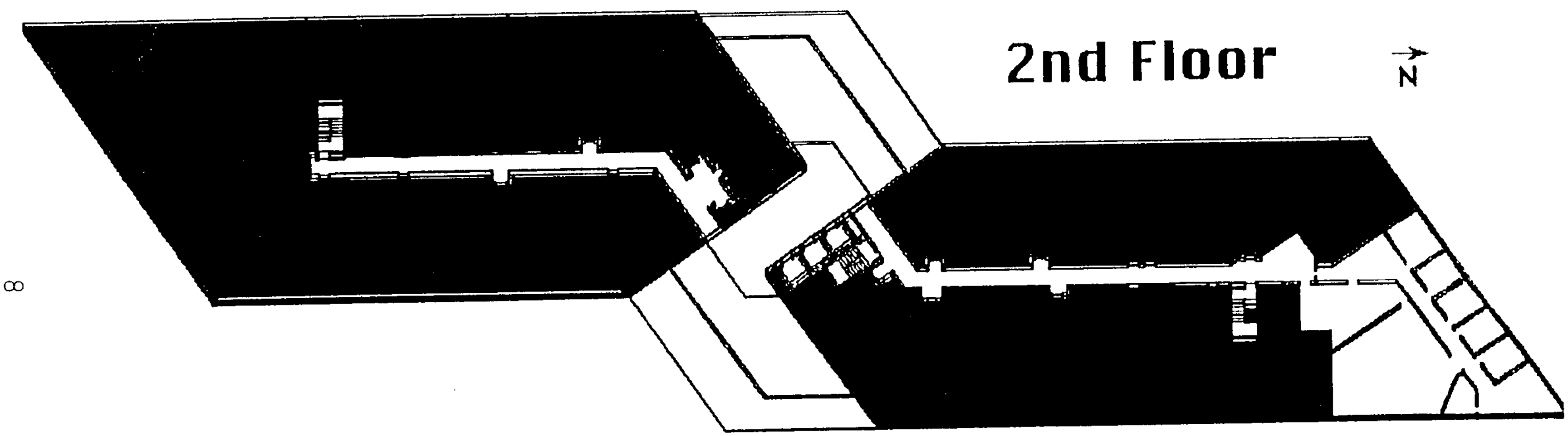

Figure 2. Areas of the Research Pavilion modeled—second floor.

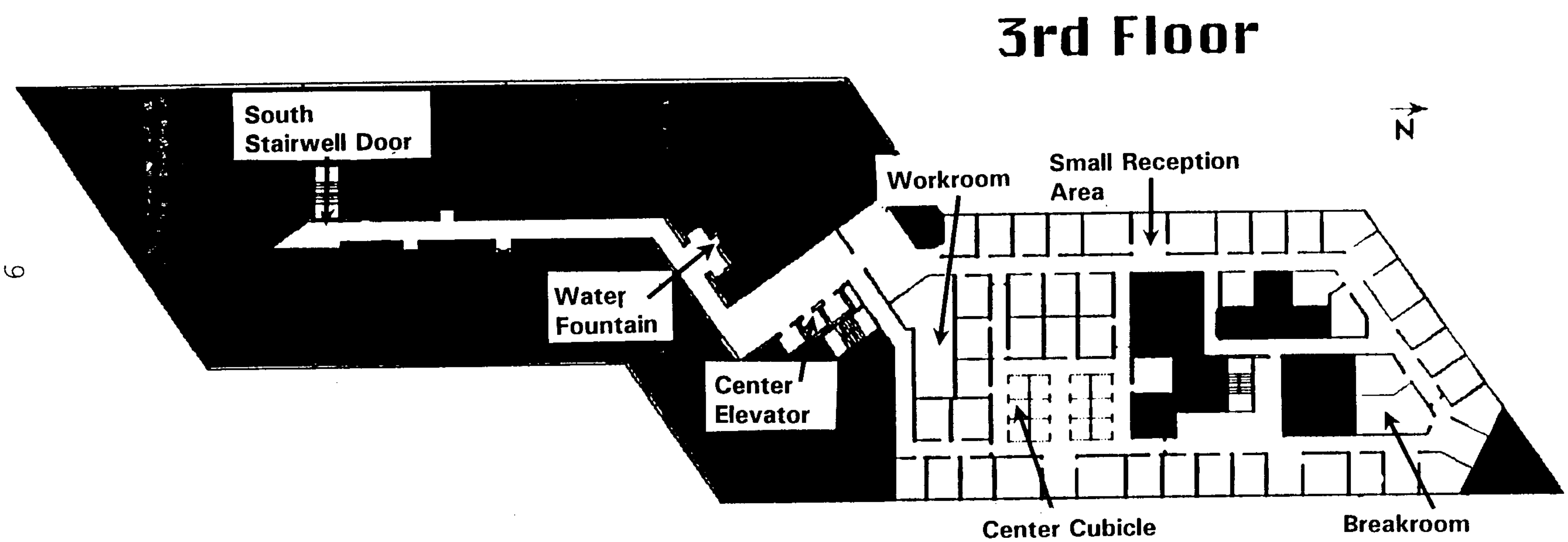

Figure 3. Areas of the Research Pavilion modeled—third floor.

The modelers had free access to all of the building spaces to be modeled. This allowed them to place and orient desks and other office furniture accurately and to make measurements if needed. The modelers also had access to some blueprints of the building. The blueprints were not complete, however, which forced the modelers to do some measurements to determine size of building features and distances between the features. The modelers took numerous photographs of furnishings to be used for texture mapping.

The hardware used to render the virtual environment consists of Silicon Graphics[tm] Crimson Reality Engine Computer and a Fakespace Lab[tm] two-color Boom2 display. The Boom2 is a high resolution binocular-like display on the end of an arm that allows six degrees of freedom movement and thumb buttons that control forward and backward motion. The Boom2 has no mechanism for controlling movement speed, so operators are unable to control their speed other than by repeatedly starting and stopping. The structural model of the building was generated using Multigen by Software Systems[tm] and WorldToolKit by Sense8 Corporation[tm]. WorldToolKit was also used to produce the operational software and the texture maps, which were used extensively in the model.

Presence and Simulator Sickness in Virtual Environments

Presence may be defined as the subjective experience of being in one place when you are physically in another (Witmer & Singer, 1994). An example is being seated in a lab located on the first floor of a building and wearing a helmet that displays images of objects lining a corridor on the third floor of the same building, and using a joystick to simulate movement through the third floor corridors. The strength of the experience of being present in a VE may vary both as a function of individual differences and the characteristics of the virtual environment that is experienced. These individual differences and VE equipment/task characteristics are what we call immersive factors. Among these factors are degree, immediacy and naturalness of control experienced by the user, the degree to which the user perceives movement, consistency of information across modalities and with the objective world, attention to external distractions, and ability to modify the physical environment (Sheridan, 1992; Held & Durlach, 1992).

Simulator sickness consists of an array of symptoms that seem to derive from elements of the visual display and visuo-vestibular interaction commonly associated with modern day simulators. The symptoms include eyestrain, difficulty focusing, blurred vision, headache, dizziness, vertigo, nausea, stomach awareness, salivation and burping (Kennedy, Lane, Berbaum, & Lilienthal, 1993). Virtual environments have been shown to produce significant simulator sickness, that may exceed that produced by standard aircraft simulators (Knerr, et al., 1994). Kennedy et al. (1993) have modified a scale used to measure motion sickness and

adapted it for measuring simulator sickness. The scale measures three dimensions (Oculomotor Discomfort, Disorientation, and Nausea), each consisting of several related symptoms that together represent the symptomology associated with sickness in simulators. The scores on each symptom are combined in an additive fashion to yield an overall Total Severity score.

Research Objectives

The main objective of this experiment was to determine the usefulness of virtual environments for training wayfinding in a complex building, by examining the extent to which skills acquired in VE transfer to real world settings. Other objectives were: (1) to assess how brief exposure to building maps contributes to route and configuration learning; (2) to examine how gender affects route and configuration learning, (3) to examine the effects of presence and simulator sickness on learning in a virtual environment; and (4) to examine other correlates of route and configuration learning (e.g., number of collisions, time in decision areas, building memory test scores, gender, and reported sense of direction).

Method

Participants

The participants were 34 female and 30 male college students enrolled in Psychology courses at the University of Central Florida. Four participants, all female, were unable to complete the research. The age of participants ranged from 18 to 53. Participants were screened to ensure that they had no previous exposure to the Research Pavilion prior to their participation in this research.

Design and Procedure

Participants were randomly assigned to one of three groups representing different training regimens with an equal number of males and females assigned to each group. These include a VE training group, a Building training group, and a Symbolic training group. Half of the male and half of the female participants in each group were trained using a map, while the other half were not given a map. Table 1 shows the number of participants in each experimental condition. For discussion purposes, this research is divided into four phases: (1) Survey phase; (2) Study phase; (3) Rehearsal phase; and (4) Test phase.

Survey Phase. All participants received a pre-brief that stated the purpose of the experiment, presented an overview of the activities that they would perform, emphasized the voluntary nature of the experiment, and discussed payment

Table 1

Number of Participants by Experimental Condition

Map Study Condition	Gender	VE Group	Symbolic Group	Building Group
Map (n = 30)	Male (n = 15)	5	5	5
	Female (n = 15)	5	5	5
No Map (n = 30)	Male (n = 15)	5	5	5
	Female (n = 15)	5	5	5

procedures. Participants had the option of receiving monetary compensation or class credit for their participation. Following the pre-brief, participants completed a short demographic questionnaire, then took the building memory test (Ekstrom, French, Harmen, & Dermen, 1990). The building memory test requires participants to recall the location of different-shaped buildings on a map. Participants in the VE group also completed a Simulator Sickness Questionnaire (SSQ) (Kennedy, et al., 1993) and an Immersive Tendencies Questionnaire (ITQ) (Witmer & Singer, 1994). The VE group also received the Simulator Sickness Questionnaire and a Presence Questionnaire (PQ) (Witmer & Singer, 1994) following their last rehearsal in the virtual building. The ITQ is typically administered prior to exposure to an immersive environment and measures an individual's tendency to become involved in a range of immersive experiences. In contrast, the PQ is typically administered immediately following exposure to an immersive environment and is designed to measure how much presence was experienced in that environment. The SSQ asks participants to rate the severity of symptoms they experience following simulator exposure. The SSQ is included as Appendix A, the ITQ as Appendix B, and the PQ as Appendix C.

Study phase. Participants studied a designated route through the Research Pavilion for 15 minutes using the materials provided. The materials included step-by-step directions along the route, color photographs of landmarks and destinations, and for those participants in the map condition, a map of each floor of the Research Pavilion with the route and destinations clearly marked.

Rehearsal phase. After studying the materials for 15 minutes, participants rehearsed the route three times. The type of rehearsal depended on their group assignment. The symbolic group verbally rehearsed the directions aloud, recalling pertinent information about turns and landmarks that had been purposely deleted (for rehearsal purposes) from the written protocol that they had studied earlier. The VE group rehearsed the route by following the route in the virtual environment,

using the Fakespace BOOM2 as the interface device. The building group rehearsed the route by following it in the Research Pavilion itself. During rehearsal, the experimenter asked participants to follow the route that they had studied earlier, stopping at each of the six destinations along the route and identifying each by name. Participants were corrected immediately if they took a wrong turn or incorrectly identified a destination. VE subjects who made a wrong turn were warned by series of beeps, while building and symbolic group subjects were warned verbally that they had taken a wrong turn. The time taken by each participant to complete each rehearsal trial was recorded. In the VE rehearsal, accuracy was measured by recording the number of attempted incorrect turns. In the building and symbolic rehearsals, accuracy was measured by recording the number directions completed correctly. Following the third rehearsal trial, participants trained in the virtual environment completed the Simulator Sickness Questionnaire and the Presence Questionnaire.

During rehearsal in the VE, additional variables were recorded automatically at 1/2 second intervals. Body position was recorded as an X, Y, Z coordinate, and head position was recorded as a yaw, pitch , and roll coordinate. From these data, summary data were derived for each area of the route and for each route rehearsal. Route sections were identified by a segment number, decision area number, or a room number. Decision areas were conceptually defined as a point in the route that required a directional choice to be made. Decision areas were operationally defined as a section of hallway extending 10 feet in every direction from the center of an intersection. In addition to decision areas, the route was divided into 70 segments of 20 feet each, and all rooms, stairways, and destinations were assigned a unique identification number. Some segments overlapped decision areas. Other data recorded every 1/2 second included whether a collision with the virtual walls had occurred or an attempted wrong turn was made, and the cumulative time since the beginning of the rehearsal. A collision occurs whenever the participants' body position coincides with the boundary of a solid object such as a wall or closed door. Upon colliding with such an object, the participant may become "stuck" on the object and must move away from the object to continue.

Summary variables were derived for each area and for each rehearsal trial from the variables recorded every 1/2 second. Variables summed for each area included: (1) time spent in the area; (2) total head movement calculated as an algebraic sum of change for roll, pitch, and yaw; (3) total number of collisions; and (4) the total number of wrong turns. Variables summed for each rehearsal trial included: (1) time spent on each floor; (2) time to reach each of six destinations; (3) time spent looking at each of 10 objects that were selected based on landmark value; (4) the total time spent looking at all 10 objects; (5) the total number of collisions; (6) total time spent colliding; (7) the total number of wrong turns; (8) the total amount of head movement; (9) the time spent in segments, in rooms, in decision areas, and in stairways; and (10) the total time to complete the rehearsal.

Test phase. Following the third rehearsal trial, all participants were tested in the Research Pavilion. Before the test began, length of the participant's stride was measured by averaging the stride length over 10 steps. Participants were then instructed to follow the route that they had rehearsed. They were asked to stop briefly at each of the six destinations and identify each one by name. The experimenter followed closely behind the participants, recording any wrong turns or misidentified destinations. If the participants made a wrong turn, they were told to stop and try a different direction. The experimenter used a stopwatch to record the time to reach each destination and the time to traverse the entire route. A pedometer attached to the participant's waistband or belt recorded the number of steps taken along the route. These measures were used as indicators of how well the participants had learned the route.

The participants also performed two tasks designed to assess their configurational knowledge about the building. In the first task, the participant was taken to the lobby area of the third floor via the elevator and told to exit the building as quickly as possible using the most direct route. The participants were not allowed to use the elevator in performing the task. The experimenter recorded the time to exit and the distance traveled in finding an exit.

In the second task, participants estimated the distance and direction from three sighting locations on the third floor of the building to four different goal locations (not in the line of sight) on the same floor. The sighting locations and goal locations are listed in Table 2, and their locale on the third floor is shown in Figure 3.

Table 2

Sighting and Goal Locations Used in Testing Configuration Knowledge

Sighting Locations	Goal Locations			
Breakroom	Center Elevator	South Stairwell Door	Small Reception Area	Water Fountain
Workroom	Center Elevator	South Stairwell Door	Small Reception Area	Water Fountain
Center Cubicle	Center Elevator	South Stairwell Door	Small Reception Area	Water Fountain

The distance and direction were estimated using the projective convergence technique (Siegel, 1981). The participant viewed an 8.5 by 11 inch blank piece of

paper through a plastic transparency displaying the outline of the Research Pavilion. A dot on the transparency represented one of the three sighting locations in the Research Pavilion. The direction and distance to a named goal location was indicated by drawing a straight line from the sighting location to a point that represented the goal location. When all four goal locations had been presented for a single sighting location, another sighting location was introduced and the procedure repeated until lines had been drawn from all sighting locations to all goal locations. The lines drawn on the plastic overlay could not be seen by the participant, but were recorded on a map of the third floor that was placed beneath the blank sheet of paper and a piece of carbon paper.

The dependent measures obtained for each goal location from the projective convergence test were consistency, accuracy, average distance error, and average miss distance. Consistency was the perimeter (scaled to feet) of the triangle formed by linking the endpoints of the vectors from each sighting location. Accuracy was the distance from the geometric center of the triangle to the goal location. Average distance error was the difference of the length of a drawn vector and the actual, accurate vector averaged across three sighting locations. Average miss distance was the distance from the endpoint of each drawn vector to the target averaged across sighting locations.

Analyses. The major research objective was to assess differences in training transfer as a function of rehearsal mode (Group effect). These differences were evaluated using a MANOVA with Group, Map and Gender as the independent measures. Dependent measures were route traversal time, number of wrong turns and total distance traveled in completing the route. Significant MANOVAs were followed by ANOVAs for each dependent measure. Post hoc comparisons were performed following significant ANOVAs to identify the source of significant effects.

In practicing the route, participants might be expected to acquire some incidental knowledge about the building configuration. Configuration knowledge was measured using the projective convergence technique, and by measuring the capability of participants to exit the building quickly using an unrehearsed route. MANOVA was used to assess differences in the amount of configuration knowledge as a function of rehearsal mode, map use, and gender. The dependent variables were obtained from two separate tasks designed to reflect configurational knowledge. Exit distance and time to exit, recorded in the building exit task, and the projective convergence measures consistency, accuracy, average distance error, and average miss distance were the dependent variables.

Correlation coefficients were calculated to determine the relationships between a number of variables and measures of route and configuration learning. Partial correlation coefficients, correcting for gender effects, were computed for the

measures of configuration learning in order to detect any spurious relationships.

Four participants assigned to the VE group dropped out of the experiment because of severe simulator sickness symptoms. Unless otherwise noted, all analyses were based on the remaining 60 participants.

Results and Discussion

Route Learning

Training transfer. A MANOVA was used to evaluate the effects of training group, map, and gender on the transfer of route learning to the actual building. There was a significant main effect for group (training medium), Wilks $F(6,92) = 11.16$, $p < .001$, while an apparent increase in performance due to map use was not statistically significant. Gender had no significant effects on route learning. A univariate ANOVA indicated that the group effect was significant for each of the dependent measures: route traversal time, $F(2,48) = 26.54$, $p < .001$; number of wrong turns, $F(2,48) = 35.69$, $p < .001$; and total distance traveled, $F(2,48) = 3.63$, $p < .05$. Newman-Keuls post hoc comparisons showed that participants trained in the building made fewer wrong turns, $p < .05$, than did participants who were trained in the VE. VE participants, in turn, made fewer wrong turns, $p < .001$, and took less time to traverse the route, $p < .001$, than did participants who were trained symbolically (i.e, using only written directions, photographs, and for half of this group, a map). Means and standard deviations by group, map and gender are presented for wrong turns in Table D-1, for route traversal time in Table D-2, and for total distance in Table D-3 (see Appendix D).

Although Building group participants made significantly fewer wrong turns in the transfer test than those in the VE group, the low number of wrong turns made by the VE group, relative to the number of possible wrong turns, indicates strong positive transfer. During route rehearsal and on the building transfer test, wrong turns were recorded if the participant turned the wrong way at an intersection, tried to go into a non-route room, or back-tracked along the route. Counting both rooms and intersections, there were more than 100 places where a wrong turn could be made. The number of wrong turns actually attempted could be much larger due to backtracking and repeatedly attempting to make the same wrong turn.

The complexity of a route can be described by route length, the number of required changes in direction, and by the total number of decision areas (Best, 1969). Decision areas in a building usually comprise intersecting hallways that require a directional choice to be made. Decision areas can be assigned a probability number based on the number directional choices. A two-choice decision area would be assigned 0.5 because there is a 50% chance of making the correct

directional choice. The probability of correctly following a route can be calculated by multiplying successive decision area probabilities.

The route in this experiment was approximately 1500 feet long. There were 41 directional changes and 47 two-choice decision areas, not counting non-destination rooms. Participants were informed immediately if they made a wrong turn, permitting them to correct their error. The probability of someone with no knowledge of the route following it correctly through the building without making a wrong turn is 0.5**47, which equals 7.1^{-15}. Note that two of the VE participants made no wrong turns. By chance alone, we would expect a participant with no route training to make a minimum of 47/2, or 23.5, wrong turns. This does not include wrong turns due to backtracking, making the same wrong turn repeatedly, or turning into rooms other than those designated as destinations. Nevertheless, this number is considerably higher than the average number of wrong turns made by any of the groups on the test of training transfer. The Building group averaged 1.10 wrong turns, while the VE group averaged 3.30. Even the Symbolic group averaged only 9.15 wrong turns, less than half the number expected by chance. Clearly both the VE and Symbolic groups exhibited transfer of training to the actual building.

<u>Route acquisition</u>. Each participant rehearsed the route three times. The change in performance over the three rehearsal trials provides an index of how quickly learning occurred in the various training conditions. The number of errors made while rehearsing the route and route rehearsal times are plotted for each trial (see Figures 4 and 5). A repeated measures ANOVA of training time with trial as

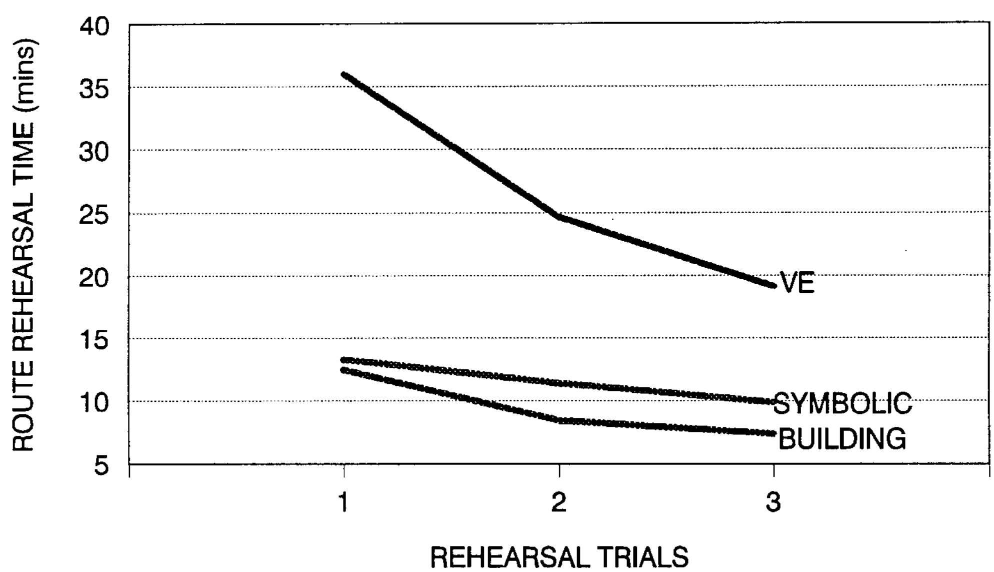

Figure 4. Route rehearsal time as a function of number of rehearsal trials and training medium.

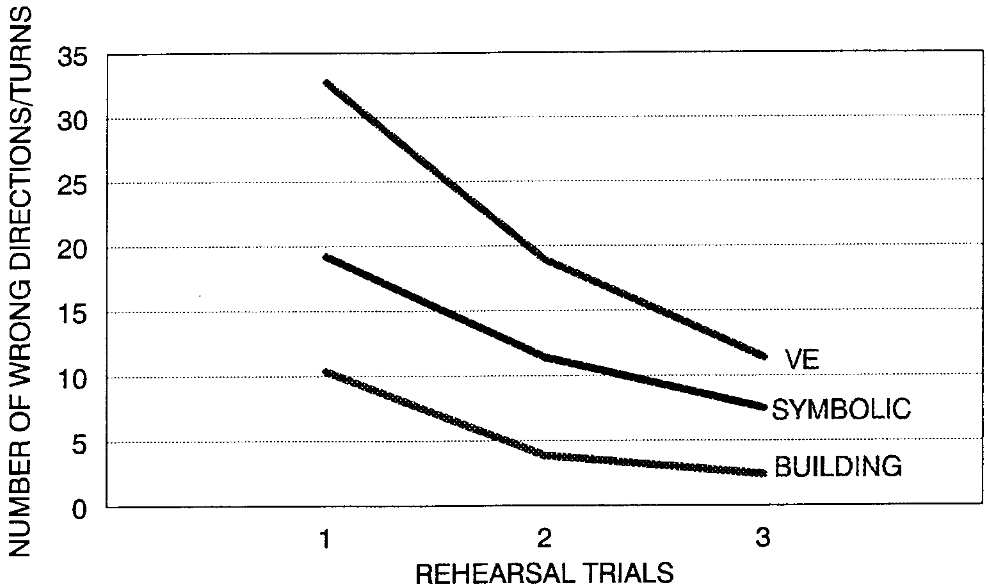

Figure 5. Route traversal errors as a function of number of rehearsal trials and training medium.

the repeated factor revealed both a significant trial effect, $\underline{F}(2,114)=141.11$, $\underline{p}<.001$, and a significant training media group effect, $\underline{F}(2,57)=128.79$, $\underline{p}<.001$. Route rehearsal times for the VE group, as shown in Figure 4, are significantly slower on each trial than the rehearsal times of the Symbolic, $\underline{p}<.001$, and Building groups, $\underline{p}<.001$, as revealed by Newman-Keuls contrasts, while the Building and Symbolic groups did not significantly differ. The trial by group interaction was also significant, $\underline{F}(4,96)=43.73$, $\underline{p}=.000$, as reflected by the steeper learning curve of the VE group, as compared to the learning curves of the symbolic and building groups. Following the significant interaction, interaction contrasts were performed using the Sheffé procedure (Marascuilo & Levine, 1970). Significant Sheffé group by trial interaction contrasts, $\underline{p}<.01$, between the VE group and each of the other two groups indicate that VE group rehearsal times decrease across trials at a faster rate from trial 1 to trial 2. Participants in the symbolic and building groups were not required to learn any new skills in addition to learning the route. The VE group, however, in addition to learning the route, needed to learn how to maneuver in the VE using the BOOM2. Learning how to maneuver in the stairs and how to maneuver off of walls after a collision may account for the slower rehearsal times and the steeper learning curve observed for the VE group.

Differences in training time. When comparing different training regimens, either the amount of time that each regimen requires or the number of training trials are almost always different. Failure to control for these differences does not

indicate a flawed experimental design because the amount of training time is inherent in the regimen. However, training time differences can make it difficult to determine whether observed differences in training regimen effectiveness are purely due to differences in the amount of training time, or due to other qualitative aspects of the regimens that are usually of interest to the researchers. As reported above, the VE group training times for each rehearsal trial were significantly greater than for either the Building or Symbolic groups.

Pearson correlation coefficients on the entire sample revealed no correlation between the total training time and number of wrong turns, $r(57) = .008$, $p = .96$, traversal time, $r(57) = -.078$, $p = .56$, or distance traveled, $r(57) = .19$, $p = .157$, in the route transfer test. However, when the training groups are considered separately, there is a significant positive correlation between total training time and the number of wrong turns made in the route transfer for the Building group, $r(20) = .53$, $p = .016$, and for the VE group, $r(17) = .49$, $p = .043$. These results indicate that longer training times are correlated with poor performance (i.e., more wrong turns) on the route transfer test. This relationship is the opposite of what might be expected if longer training times translate to better performance. The amount of time for each rehearsal was determined by the proficiency of each individual participant. Participants who had long rehearsal times may have been struggling to remember the route or, in the case of the VE group, may have had trouble in maneuvering in the virtual environment. On the average participants in the VE group collided with solid objects 74 times and spent nearly four and one-half minutes in collision with objects during each rehearsal trial.

Correlates of Route Learning

Route learning measures taken in the building were the number of wrong turns, route traversal time, and total distance traveled. A number of variables were investigated as possible predictors of route learning. One set of these variables was measured for all three of the rehearsal media. These include the number of destinations correctly recalled, building memory test scores, and reported sense of direction. A second set of variables was measured only in the virtual environment and therefore applies only to the VE group. This set includes the amount of time spent gazing at selected landmarks, the rate of head movement, the amount of presence reported, the severity of simulator sickness reported, number of collisions, time spent in collision with objects, and the total time spent in decision areas.

Correlates of route learning in the virtual environment. Table 3 presents the results of a one-tailed test of Pearson correlations between potential predictors measured in the VE and measures of route learning obtained in the building. It was expected that participants who visually explored the VE would perform better on the route test than those who did not. One potential indication of visual

exploration would be the amount of head movement per unit time. Conversely, more head movement may be associated with getting lost and trying to figure out which direction to take. A second indication of visual exploration would be the proportion of time that the participant spent directly looking at important landmarks. Neither the rate of head movement nor the proportion of time spent looking at landmarks was significantly correlated with measures of route learning.

Table 3

Correlates of Route Learning in VE: Pearson r's

Variables	Number of Wrong Turns	Route Traversal Time	Route Traversal Distance
Route Traversal TIme	0.61**	1.0	0.14
Route Traversal Distance	0.52*	0.14	1.0
Head Movement	-0.05	0.04	0.05
Landmark Gaze Time	0.12	0.18	0.00
Number of Collisions	0.45*	0.12	0.12
Collision Time	0.46*	0.21	0.25
Decision Time	0.65**	0.27	0.26
PQ	-0.21	-0.19	-0.23
ITQ	0.12	0.16	0.19
SSQ	0.12	0.02	0.19

Based on a one-tailed test of significance, * $p<.05$, ** $p<.01$, *** $p<.001$

Participants who experience more presence in the VE (higher PQ scores) would also be expected to have shorter route traversal times, make fewer wrong turns and cover less distance in traversing the route than the other participants. The amount of presence, as measured by the PQ, was correlated with better performance for all three measures of route learning. The correlations between the PQ and route learning measures were not significant, however. PQ was negatively correlated with number of wrong turns, r = -.21, route traversal time, r = -.19 , and distance traveled in traversing the route, r = -.23 . This result is consistent

with previous research findings (Witmer & Singer, 1994) that show higher PQ scores to be associated with better task performance. The correlation between presence and task performance in this study is not as strong as that obtained previously, in which Witmer and Singer (1994) found some measures of performance to be significantly related to presence. In contrast, participants who collide often with solid objects in the VE, and those who spend more time stuck on those objects, would be expected to perform more poorly than the other participants. The number of wrong turns made on the test was significantly correlated with both the number of collisions with solid objects in the VE, r = .45, p<.05, and with the time spent colliding with those objects, r = .46, p<.05. Significant correlations with route traversal time and route distance were not obtained.

Similarly participants who experience significant simulator sickness in the VE would not be expected to perform as well on the transfer test as those participants who do not experience any symptoms. While participants who reported more simulator sickness made more wrong turns, took more time, and traveled further in completing the route test than those who reported fewer symptoms, the correlations were low and not statistically significant at the .05 level.

Participants who spend a lot of time in decision areas during route rehearsal would seem not to be learning the route as well as their more decisive counterparts and therefore would not be expected to perform as well on the route test as those who spend less time in the decision areas during training. As expected participants who spent more time in decision areas during training made significantly more wrong turns in traversing the route during the test, r=.65, p<.01. Even when total training time and collision time were controlled through partial correlation, a significant positive correlation between the time spent in decision areas and number of wrong turns was found, r=.47, p<.05 .

Correlates of route learning across training media. Table 4 presents the results of a one-tailed test of Pearson correlations between potential predictors across training media and measures of route learning obtained in the building. Each destination may be considered a landmark along the route. Attention to these landmarks should be associated with better recall of these landmarks on the test. Therefore participants who recall landmarks better might be expected to demonstrate better route learning than those who paid less attention to and did not remember the landmarks as well. As expected, participants who correctly identified more destinations made fewer wrong turns, r = -.84, p < .001, traversed the route more quickly, r = -.78, p < .001, and traveled less distance in traversing the route, r = -.28, p < .05. Likewise participants who performed better on the building memory test might be expected to outperform their fellow participants on the transfer test. Contrary to expectation, scores on the building memory test did not predict any of the measures of route learning.

Table 4

Correlates of Route Learning Across Training Media: Pearson r's

Variables	Number of Wrong Turns	Route Traversal Time	Route Traversal Distance
Route Traversal Time	0.76**	1.0	0.35*
Route Traversal Distance	0.35*	0.35*	1.0
Gender	-0.14	-0.14	0.02
Landmark Recall	-0.84***	-0.78***	-0.28*
Building Memory	-0.02	0.00	0.16
Direction Sense	0.09	0.17	0.05

Based on a one-tailed test of significance, * $p<.05$, ** $p<.01$, *** $p<.001$

Participants who report having a good sense of direction would be expected to perform better on the transfer test than those who say that they don't have a good sense of direction. The expected relationship between sense of direction and measures of route learning was not found, however.

Configuration Learning

Training transfer. The route through the Research Pavilion covered a significant portion of the building. In rehearsing the route three times, participants may also acquire knowledge of the building configuration. Acquisition of configuration knowledge would be incidental, however, because the training was designed to impart route knowledge rather than configuration knowledge. Also note that the amount of experience provided with the building in this experiment might be considered a minimal amount to impart configurational knowledge, particularly when compared with the naturalistic way of acquiring such knowledge by experiencing repeated exposures over an extended period of time.

A MANOVA was used to determine if there were any effects of group (i.e. training strategy), map, and gender on the amount of configurational knowledge acquired. Contrary to expectations, there were no significant main effects for group, Wilks $F(12,86) = .67$, $p = .135$, or for map use, $F(6,43) = .87$, $p = .384$. There was, however, a significant main effect of gender, Wilks $F(6, 43) = 3.03$, $p < .05$, with males performing better than females. Other gender effects, revealed by univariate ANOVAs, included significant differences in the average miss

distance, $F(1, 48) = 5.45$, $p < .05$, in average distance error, $F(1, 48) = 10.59$, $p < .01$, and in the time to exit the building, $F(1, 48) = 8.44$, $p < .01$. No significant interactions were found. Means and standard deviations by group, map, and gender are presented for projective convergence measures in Tables E-1, E-2, E-3, and E-4, for building exit time in Table E-5, and for exit distance in Table E-6 (see Appendix E).

Acquisition of configuration knowledge. No measures of configuration learning were taken during either the study phase or during the rehearsal trials, but we expected that those participants who were given maps to study would demonstrate superior configuration knowledge on the transfer tests. However, no relationship between map use during acquisition and configuration knowledge was found. The groups who had direct experience with the building or the building model might have been expected to exhibit superior configuration knowledge than the symbolic group, yet no significant differences were obtained.

Correlates of Configuration Knowledge

A number of variables were investigated as possible predictors of configuration knowledge. A subset of these variables, to include gender, the number of destinations correctly recalled, building memory test scores, and reported sense of direction, was measured for all three of the rehearsal media. A second subset was measured only in the virtual environment, and therefore applies only to the VE group. This subset includes the amount of time spent gazing at selected landmarks, the rate of head movement, the amount of presence reported, the severity of simulator sickness reported, number of collisions, time spent in collision with objects, and the total time spent in decision areas. Table 5 shows the Pearson r's for the VE group and the results of a one-tailed test of significance.

Correlates of configuration knowledge in the virtual environment. Visual exploration as measured by the amount of head movement per unit time should be associated with measures of configuration learning. As expected, participants who moved their head more, relative to other participants, performed significantly better on three of six measures of configuration learning, $p < .05$. More head movement was significantly associated with better accuracy, lower average distance error, and lower average miss distance measures on the projective convergence test, but was not related to configuration learning as measured by the building exit test. The proportion of time spent looking at important landmarks was not significantly associated with measures of configuration learning.

Participants who report a greater tendency to become immersed or who experience a greater degree of presence in the VE as measured by the ITQ and PQ scales would also be expected to perform better on the configuration knowledge test than the other participants. Higher scores on these scales were associated

Table 5

Correlates of Configuration Knowledge in VE: Pearson r's

Variables	Consis-tency	Accu-racy	Distance Error	Miss Distance	Exit Time	Exit Distance
Accuracy	0.50*	1.0	0.86***	0.94***	-0.20	-0.25
Distance Error	0.79***	0.86***	1.0	0.92***	0.04	-0.14
Miss Distance	0.66**	0.94***	0.92***	1.0	-0.04	-0.12
Exit Time	0.45*	-0.20	0.04	-0.04	1.0	0.80***
Exit Distance	0.21	-0.25	-0.14	-0.12	0.80***	1.0
Head Movement	-0.36	-0.42*	-0.41*	-0.45*	0.13	0.17
Landmark Gaze Time	0.11	0.19	0.16	0.15	0.27	0.20
Number of Collisions	0.14	-0.01	0.07	0.05	0.10	0.27
Collision Time	0.39	0.15	0.31	0.26	0.19	0.29
Decision Time	0.36	0.31	0.23	0.36	-0.14	0.07
ITQ Score	-0.38*	-0.42*	-0.48*	-0.49*	-0.21	-0.01
PQ Score	-0.11	-0.15	-0.19	-0.11	-0.14	-0.27
SSQ Score	0.08	0.13	0.06	0.15	0.21	0.41*

Based on a one-tailed test of significance, *$p<.05$, **$p<.01$, ***$p<.001$

with superior performance on the configuration knowledge test. Scores on the ITQ scale were significantly correlated, $p < .05$, with all four measures of configuration knowledge for the projective convergence task. None of the remaining correlation coefficients were significant. Partialling out gender did not substantially alter the relationship between ITQ scale scores and configuration knowledge.

In contrast participants who collide often with objects in the VE and those who spend more time stuck on those objects would be expected to perform more poorly than other participants. Similarly, participants reporting significant simulator sickness in the VE could be expected to perform less well on tests of configuration knowledge than participants who did not experience any symptoms. While simulator sickness was associated with poorer performance on tests of configuration knowledge, the relationship between these measures was weak and, with the exception of exit distance, $r = .41$, $p < .05$, not significant. Neither number of collisions nor collision time were significant predictors of configuration learning.

Participants who spend more time in decision areas during route rehearsal would seem not to be learning the building configuration as well as their more decisive counterparts, and hence would not be expected to perform as well on the configuration learning tests as those who spend less time in the decision areas during rehearsal. However, there were no significant correlations between time spent in decision areas and performance on measures of configuration learning.

Correlates of configuration knowledge across training media. Table 6 shows the correlations with measures of configuration knowledge across training media. Gender was significantly correlated with all six measures of configuration knowledge, with males outperforming females. This is in stark contrast to the route learning test results that showed gender to be unrelated to performance.

Each destination may be considered a landmark along the route. Attention to these landmarks should be associated with better recall of these landmarks on the test. Remembering these landmarks should enhance performance on the projective convergence test because some of the landmarks were used as sighting or goal locations. Recalling the landmarks correctly on the route test was significantly correlated with the accuracy, $r = -.23$, $p < .05$, and average miss distance, $r = -.23$, $p < .05$, on the projective convergence test.

Participants who score better on the building memory test could be expected to learn more about the building configuration than those with lower scores. The data did not support this hypotheses, however, with the correlations between measures of configuration learning and building memory clustering near zero. When gender differences in building memory scores are removed through partial correlation, one measure of configuration learning - average miss distance - is significantly correlated with scores on the building memory test, $r = -.25$, $p < .05$. Females performed better on the building memory test than did males.

Participants who reported having a good sense of direction performed better on tests of configuration knowledge than those who did not. Sense of direction as reported by participants was significantly correlated with consistency, $r = -.27$, $p < .05$, average distance error, $r = -.30$, $p < .01$, and average miss distance, $r = -$

Table 6

Correlates of Configuration Knowledge Across Training Media: Pearson r's

Variables	Consis-tency	Accu-racy	Distance Error	Miss Distance	Exit Time	Exit Distance
Accuracy	0.38**	1.0	0.77***	0.94***	-0.10	-0.31**
Distance Error	0.49***	0.77***	1.0	0.80***	0.16	-0.17
Miss Distance	0.52***	0.94***	0.80***	1.0	-0.04	-0.23*
Exit Time	0.09	-0.10	0.16	-0.04	1.0	0.79***
Exit Distance	-0.00	-0.31**	-0.17	-0.23*	0.79***	1.0
Gender	-0.25*	-0.25*	-0.39***	-0.30**	-0.36**	-0.22*
Building Memory	0.01	-0.10	-0.03	-0.16	-0.02	0.08
Direction Sense	-0.27*	-0.17	-0.30**	-0.27*	-0.18	-0.02
Landmark Recall	-0.13	-0.23*	0.04	-0.23*	-0.08	-0.19

Based on a one-tailed test of significance, * $p<.05$, ** $p<.01$, *** $p<.001$

.27, $p<.05$, for the projective convergence test. However, when the effects of gender were partialled out, the correlations between sense of direction and configuration knowledge were reduced and failed to reach statistical significance. Males generally reported a better sense of direction than females and performed better on the tests of configuration knowledge.

Presence

The participants who experienced the virtual environment reported feeling present in that environment. Scores on the Presence Questionnaire (PQ) ranged from 117 to 184 (M = 147.25, SD = 15.2). Immersive Tendencies Questionnaire (ITQ) scores ranged from 84 to 144 (M = 115.85, SD = 16.51). A small nonsignificant correlation was obtained between ITQ scores and PQ scores, r = -.10, p = .335. Thus, the ITQ did not predict the amount of presence experienced in the virtual environment. On the other hand, a strong negative

correlation was obtained between the Simulator Sickness Questionnaire scores and the PQ scores, $r = -.60$, $p < .01$. One might expect participants who focus on feelings of discomfort due to simulator sickness to report less presence in VE than someone who is not feeling sick and can concentrate more on other aspects (e.g., images, sound, task characteristics) of the virtual environment.

Simulator Sickness

Some of the participants in this research reported simulator sickness symptoms after exposure to the virtual environment. The severity of the symptoms that were reported varied from no symptoms to severe sickness. Total Severity scores on the SSQ scale ranged from 0 to 130.9 ($M = 32.35$, $SD = 40.63$) for the 20 VE group participants who completed the experiment. When the four participants who failed to complete the experiment were added into the sample, the SSQ Total Severity scores ranged from 0 to 130.9 ($M = 37.87$, $SD = 39.34$). All four of the participants who voluntarily withdrew from the experiment because of severe simulator sickness were females. The SSQ Total Severity scores of these four participants ranged from 48.6 to 82.3 ($M = 65.45$, $SD = 13.83$).

Table 7 shows the Simulator Sickness questionnaire results for the 20 participants who completed the experiment broken down into three subscales: Nausea subscale, Oculomotor Discomfort subscale, and the Disorientation subscale. Results are presented by gender. Results indicate that female participants reported higher simulator sickness scores than male participants following exposure to the virtual environment. The SSQ Total Severity score differences between male and female participants were not significant, however, $t = 1.46$, $p > .161$. No significant gender differences were obtained for any of the subscales.

Table 7

Simulator Sickness Questionnaire Results by Gender

Gender	SSQ Subscale Scores			SSQ Total Severity Score
	Nausea	Oculomotor Discomfort	Disorientation	
Female $N = 10$	$M = 21.94$ $SD = 32.13$	$M = 43.21$ $SD = 48.87$	$M = 57.07$ $SD = 76.37$	$M = 45.25$ $SD = 54.21$
Male $N = 10$	$M = 10.49$ $SD = 12.28$	$M = 21.98$ $SD = 16.16$	$M = 16.70$ $SD = 19.47$	$M = 19.45$ $SD = 13.29$

When the four participants who could not complete the experiment are included in the analysis ($\underline{N}=24$), significant differences between male and female participants were obtained for the Total Severity scores, $\underline{t}=2.07$, $\underline{p}<.05$, and for the Disorientation subscale scores, $\underline{t}=2.14$, $\underline{p}<.05$.

Conclusions

If virtual environments are to be used for training, it is essential that skills learned in virtual environments transfer to real world settings. This research demonstrated that virtual environments can be created that are nearly as effective as real world environments in training participants to follow a specified route. We were not successful in demonstrating configuration learning for any training medium, or in showing differences in configuration knowledge as a function of the training medium employed. It should be noted, however, that no specific attempt was made to train configuration knowledge; rather we thought it might be acquired incidentally in learning the route. Further research will be needed to determine the relative effectiveness of VE in training configuration knowledge.

Transfer of training of route learning skills from the virtual environment to the real building was demonstrated despite using VE technology that is developmentally still in its infancy. The virtual environment that we used was primarily visual; the environment did not allow participants to manipulate objects in the environment or explore the environment through touch, nor did it provide any aural cues other than the beeps indicating a wrong turn. It did allow participants to move around inside the virtual building and to direct their gaze in whatever direction and at whatever objects they wished to view. Their movement in the virtual world was constrained as it would be in the real world by solid walls, locked doors and other solid objects. Other doors (e.g., stairway doors) would open automatically when approached to allow the participants to pass through.

In this research, the use of a map during the 15-minute study phase did not have a significant effect on performance. In addition to studying the map, participants were given photographs and written directions to study. Given the complexity of the route and the additional study materials, it is unlikely that the participants were able to devote enough time to map study to commit it to memory. This may explain the lack of a significant map effect in this research.

One problem with the virtual environment used in this research is that it tends to induce simulator sickness in participants. While some participants experienced no apparent symptoms or reported only mild symptoms, four were so sick that they could not complete the research task. Others completed the task through sheer determination, despite reporting severe simulator sickness symptoms. Some of these appeared to rush through the route in order to escape the virtual environment - the source of their discomfort. The simulator sickness

reported resulting from exposure to the virtual building was more severe than has been reported for the typical aircraft simulator (Kennedy et al., 1992). While the severity of simulator sickness reported in this study is relatively high, only one significant correlation between simulator sickness severity scores and measures of performance was found. It is rather surprising that learning in the virtual building was not more affected by the severity of simulator sickness symptoms experienced. It does appear, however, that participants who experience simulator sickness in the virtual environment may experience less presence in that environment. The high negative correlation between PQ scores and SSQ scores may indicate that experiencing simulator sickness can decrease the amount of presence experienced in virtual environments.

Higher presence scores as measured by the Presence Questionnaire (PQ) were weakly associated with better performance on tests of route learning and building configuration learning. This observation is consistent with results obtained in an earlier experiment (Witmer & Singer, 1994). In that experiment, higher levels of presence as reported on the PQ were associated with better performance on some tests in the Virtual Environment Performance Assessment Battery. The reported relationships between presence and either route or configuration learning are tenuous however, and further research is required before we can draw any conclusions.

The Immersive Tendencies Questionnaire (ITQ) was not a good predictor of route learning but was the best predictor of configuration learning as measured by the projective convergence test. It is not clear why this result occurred. However, participants who had a strong tendency to actively involve themselves in a number of activities as measured by the ITQ may have been more confident in their ability to estimate the direction and distance to unseen locations and might have been less prone to guess on this difficult task. A related explanation is that participants who involve themselves in a number of activities may be more competent than their peers, or else become more competent as the result of that involvement.

Configuration learning varied significantly as a function of gender, but neither the use of a map nor the manner in which participants rehearsed the route had a significant effect on measures of configuration learning. The gender effect was not expected, but was consistent with other research where gender differences in spatial abilities, if found, usually favor males.

This research has successfully demonstrated that virtual environments can be developed that train real world skills and that the effectiveness of these environments can approach that of real world training media. In addition, it has shed light on some of the predictors of spatial skill transfer both in virtual and real world environments. Finally, it has provided interesting data on presence, simulator sickness and the relationship between these two constructs.

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Appendix A. Simulator Sickness Questionnaire (SSQ)

Symptom Checklist

Instructions: Please indicate the severity of symptoms that apply to you right now.

1.	General Discomfort	None	Slight	Moderate	Severe
2.	Fatigue	None	Slight	Moderate	Severe
3.	Headache	None	Slight	Moderate	Severe
4.	Eye Strain	None	Slight	Moderate	Severe
5.	Difficulty Focusing	None	Slight	Moderate	Severe
6.	Increased Salivation	None	Slight	Moderate	Severe
7.	Sweating	None	Slight	Moderate	Severe
8.	Nausea	None	Slight	Moderate	Severe
9.	Difficulty Concentrating	None	Slight	Moderate	Severe
10.	Fullness of Head	None	Slight	Moderate	Severe
11.	Blurred vision	None	Slight	Moderate	Severe
12.	Dizzy (Eyes Open)	None	Slight	Moderate	Severe
13.	Dizzy (Eyes Closed)	None	Slight	Moderate	Severe
14.	Vertigo*	None	Slight	Moderate	Severe
15.	Stomach Awareness	None	Slight	Moderate	Severe
16.	Burping	None	Slight	Moderate	Severe
17.	Boredom	None	Slight	Moderate	Severe
18.	Drowsiness	None	Slight	Moderate	Severe
19.	Decreased Salivation	None	Slight	Moderate	Severe
20.	Mental Depression	None	Slight	Moderate	Severe
21.	Visual Flashbacks	None	Slight	Moderate	Severe
22.	Faintness	None	Slight	Moderate	Severe
23.	Aware of Breathing	None	Slight	Moderate	Severe
24.	Loss of Appetite	None	Slight	Moderate	Severe
25.	Increased Appetite	None	Slight	Moderate	Severe
26.	Desire to move bowels	None	Slight	Moderate	Severe
27.	Confusion	None	Slight	Moderate	Severe
28.	Vomiting	None	Slight	Moderate	Severe

*Vertigo is a disordered state in which the person or his surroundings seem to whirl dizzily: giddiness.

Note. Items 1 through 16 are used for SSQ scoring. The additional 12 items were included to collect data for use in future scale revisions.

Appendix B. Immersive Tendencies Questionnaire (ITQ)
Version 2, Bob Witmer & Michael J. Singer

Indicate your preferred answer by marking an "X" in the appropriate box of the seven point scale. Please consider the entire scale when making your responses, as the intermediate levels may apply. For example, if your response is once or twice, the second box from the left should be marked. If your response is many times but not extremely often, then the sixth (or second box from the right) should be marked.

1. Do you ever get extremely involved in projects that are assigned to you by your boss or your instructor, to the exclusion of other tasks?

|________|________|________|________|________|________|________|

NEVER OCCASIONALLY OFTEN

2. How easily can you switch your attention from the task in which you are currently involved to a new task?

|________|________|________|________|________|________|________|

NOT SO EASILY FAIRLY EASILY QUITE EASILY

3. How frequently do you get emotionally involved (angry, sad, or happy) in the news stories that you read or hear?

|________|________|________|________|________|________|________|

NEVER OCCASIONALLY OFTEN

4. How well do you feel today?

|________|________|________|________|________|________|________|

NOT WELL PRETTY WELL EXCELLENT

5. Do you easily become deeply involved in movies or tv dramas?

|________|________|________|________|________|________|________|

NEVER OCCASIONALLY OFTEN

6. Do you ever become so involved in a television program or book that people have problems getting your attention?

|________|________|________|________|________|________|________|

NEVER OCCASIONALLY OFTEN

7. How mentally alert do you feel at the present time?

|________|________|________|________|________|________|________|

NOT ALERT MODERATELY FULLY ALERT

8. Do you ever become so involved in a movie that you are not aware of things happening around you?

|________|________|________|________|________|________|________|

NEVER OCCASIONALLY OFTEN

9. How frequently do you find yourself closely identifying with the characters in a story line?

|________|________|________|________|________|________|________|

NEVER OCCASIONALLY OFTEN

10. Do you ever become so involved in a video game that it is as if you are inside the game rather than moving a joystick and watching the screen?

|________|________|________|________|________|________|________|

NEVER OCCASIONALLY OFTEN

11. On average, how many books do you read for enjoyment in a month?

|________|________|________|________|________|________|________|

NONE ONE TWO THREE FOUR FIVE MORE

12. What kind of books do you read most frequently? (CIRCLE ONE ITEM ONLY!)

Spy novels	Fantasies	Science fiction
Adventure novels	Romance novels	Historical novels
Westerns	Mysteries	Other fiction
Biographies	Autobiographies	Other non-fiction

13. How physically fit do you feel today?

|________|________|________|________|________|________|________|

NOT FIT MODERATELY FIT EXTREMELY FIT

14. How good are you at blocking out external distractions when you are involved in something?

|________|________|________|________|________|________|________|

NOT VERY GOOD — SOMEWHAT GOOD — VERY GOOD

15. When watching sports, do you ever become so involved in the game that you react as if you were one of the players?

|________|________|________|________|________|________|________|

NEVER — OCCASIONALLY — OFTEN

16. Do you ever become so involved in a daydream that you are not aware of things happening around you?

|________|________|________|________|________|________|________|

NEVER — OCCASIONALLY — OFTEN

17. Do you ever have dreams that are so real that you feel disoriented when you awake?

|________|________|________|________|________|________|________|

NEVER — OCCASIONALLY — OFTEN

18. When playing sports, do you become so involved in the game that you lose track of time?

|________|________|________|________|________|________|________|

NEVER — OCCASIONALLY — OFTEN

19. Are you easily disturbed when working on a task?

|________|________|________|________|________|________|________|

NEVER — OCCASIONALLY — OFTEN

20. How well do you concentrate on enjoyable activities?

|________|________|________|________|________|________|________|

NOT AT ALL — MODERATELY WELL — VERY WELL

21. How often do you play arcade or video games? (OFTEN should be taken to mean every day or every two days, on average.)

|________|________|________|________|________|________|________|
NEVER OCCASIONALLY OFTEN

22. How well do you concentrate on disagreeable tasks?

|________|________|________|________|________|________|________|
NOT AT ALL MODERATELY WELL VERY WELL

23. Have you ever gotten excited during a chase or fight scene on TV or in the movies?

|________|________|________|________|________|________|________|
NEVER OCCASIONALLY OFTEN

24. To what extent have you dwelled on personal problems in the last 48 hours?

|________|________|________|________|________|________|________|
NOT AT ALL SOME ENTIRELY

25. Have you ever gotten scared by something happening on a TV show or in a movie?

|________|________|________|________|________|________|________|
NEVER OCCASIONALLY OFTEN

26. Have you ever remained apprehensive or fearful long after watching a scary movie?

|________|________|________|________|________|________|________|
NEVER OCCASIONALLY OFTEN

27. Do you ever avoid carnival or fairground rides because they are too scary?

|________|________|________|________|________|________|________|
NEVER OCCASIONALLY OFTEN

28. How frequently do you watch tv soap operas or docu-dramas?

|________|________|________|________|________|________|________|

NEVER OCCASIONALLY OFTEN

29. Do you ever become so involved in doing something that you lose all track of time?

|________|________|________|________|________|________|________|

NEVER OCCASIONALLY OFTEN

Appendix C. Presence Questionnaire (PQ)
Version 2.0, Bob Witmer & Michael J. Singer

Characterize your experience in the virtual environment, by marking an "X" in the appropriate box of the 7-point scale, in accordance with the question content and descriptive labels. Please consider the entire scale when making your responses, as the intermediate levels may apply. Answer the questions independently in the order that they appear. Do not skip questions or return to a previous question to change your answer. ANSWER ALL QUESTIONS WITH REGARD TO THE VIRTUAL ENVIRONMENT.

1. How much were you able to control events?

|________|________|________|________|________|________|________|

NOT AT ALL — SOMEWHAT — COMPLETELY

2. How responsive was the environment to actions that you initiated (or performed)?

|________|________|________|________|________|________|________|

NOT RESPONSIVE — MODERATELY RESPONSIVE — COMPLETELY RESPONSIVE

3. How natural did your interactions with the environment seem?

|________|________|________|________|________|________|________|

EXTREMELY ARTIFICIAL — BORDERLINE — COMPLETELY NATURAL

4. How completely were <u>all</u> of your senses engaged?

|________|________|________|________|________|________|________|

NOT ENGAGED — MILDLY ENGAGED — COMPLETELY ENGAGED

5. How much did the visual aspects of the environment involve you?

|________|________|________|________|________|________|________|

NOT AT ALL — SOMEWHAT — COMPLETELY

6. How much did the auditory aspects of the environment involve you?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT COMPLETELY

7. How natural was the mechanism which controlled movement through the environment?

|________|________|________|________|________|________|________|
EXTREMELY ARTIFICIAL BORDERLINE COMPLETELY NATURAL

8. How aware were you of events occurring in the real world around you?

|________|________|________|________|________|________|________|
NOT AWARE AT ALL MILDLY AWARE VERY AWARE

9. How aware were you of your display and control devices?

|________|________|________|________|________|________|________|
NOT AWARE AT ALL MILDLY AWARE VERY AWARE

10. How compelling was your sense of objects moving through space?

|________|________|________|________|________|________|________|
NOT AT ALL MODERATELY COMPELLING VERY COMPELLING

11. How inconsistent or disconnected was the information coming from your various senses?

|________|________|________|________|________|________|________|
NOT AT ALL INCONSISTENT SOMEWHAT INCONSISTENT VERY INCONSISTENT

12. How much did your experiences in the virtual environment seem consistent with your real world experiences?

|________|________|________|________|________|________|________|
NOT CONSISTENT MODERATELY CONSISTENT VERY CONSISTENT

13. Were you able to anticipate what would happen next in response to the actions that you performed?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT COMPLETELY

14. How completely were you able to actively survey or search the environment using vision?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT COMPLETELY

15. How well could you identify sounds?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT COMPLETELY

16. How well could you localize sounds?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT COMPLETELY

17. How well could you actively survey or search the virtual environment using touch?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT COMPLETELY

18. How compelling was your sense of moving around inside the virtual environment?

|________|________|________|________|________|________|________|
NOT COMPELLING MODERATELY COMPELLING VERY COMPELLING

19. How closely were you able to examine objects?

|________|________|________|________|________|________|________|
NOT AT ALL PRETTY CLOSELY VERY CLOSELY

20. How well could you examine objects from multiple viewpoints?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT EXTENSIVELY

21. How well could you move or manipulate objects in the virtual environment?

|________|________|________|________|________|________|________|
NOT AT ALL SOMEWHAT EXTENSIVELY

22. To what degree did you feel confused or disoriented at the beginning of breaks or at the end of the experimental session?

|________|________|________|________|________|________|________|
NOT AT ALL MILDLY DISORIENTED VERY DISORIENTED

23. How involved were you in the virtual environment experience?

|________|________|________|________|________|________|________|
NOT INVOLVED MILDLY INVOLVED COMPLETELY ENGROSSED

24. How distracting was the control mechanism?

|________|________|________|________|________|________|________|
NOT AT ALL MILDLY DISTRACTING VERY DISTRACTING

25. How much delay did you experience between your actions and expected outcomes?

|________|________|________|________|________|________|________|
NO DELAYS MODERATE DELAYS LONG DELAYS

26. How quickly did you adjust to the virtual environment experience?

|________|________|________|________|________|________|________|
NOT AT ALL SLOWLY LESS THAN ONE MINUTE

27. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?

|________|________|________|________|________|________|________|
NOT PROFICIENT REASONABLY PROFICIENT VERY PROFICIENT

28. How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?

|________|________|________|________|________|________|________|

NOT AT ALL — INTERFERED SOMEWHAT — PREVENTED PERFORMANCE

29. How much did the control devices interfere with the performance of assigned tasks or with other activities?

|________|________|________|________|________|________|________|

NOT AT ALL — INTERFERED SOMEWHAT — INTERFERED GREATLY

30. How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?

|________|________|________|________|________|________|________|

NOT AT ALL — SOMEWHAT — COMPLETELY

31. Did you learn new techniques that enabled you to improve your performance?

|________|________|________|________|________|________|________|

NO TECHNIQUES LEARNED — LEARNED SOME TECHNIQUES — LEARNED MANY TECHNIQUES

32. Were you involved in the experimental task to the extent that you lost track of time?

|________|________|________|________|________|________|________|

NOT AT ALL — SOMEWHAT — COMPLETELY

Appendix D. Route Transfer Test Performance Means and Standard Deviations

Table D-1

Number of Wrong Turns as a Function of Training Group, Map Usage, and Gender: Means and Standard Deviations

Training Group	Map		No Map		Entire Population
	Female	Male	Female	Male	
VE	M = 3.20 SD = 1.30	M = 1.80 SD = 2.39	M = 5.20 SD = 3.27	M = 3.00 SD = 3.08	M = 3.30 SD = 2.72
Symbolic	M = 7.00 SD = 2.35	M = 7.60 SD = 5.68	M = 13.00 SD = 2.83	M = 9.00 SD = 5.92	M = 9.15 SD = 4.77
Building	M = 1.20 SD = 1.79	M = 1.20 SD = 1.64	M = 1.40 SD = 1.14	M = 0.60 SD = 0.89	M = 1.10 SD = 1.33

Table D-2

Route Traversal Time (min) as a Function of Training Group, Map Usage, and Gender: Means and Standard Deviations

Training Group	Map		No Map		Entire Population
	Female	Male	Female	Male	
VE	M = 7.84 SD = .85	M = 7.46 SD = 1.14	M = 9.28 SD = 1.40	M = 7.79 SD = .83	M = 8.09 SD = 1.23
Symbolic	M = 10.89 SD = 1.63	M = 11.06 SD = 1.83	M = 13.46 SD = 2.13	M = 10.78 SD = 3.12	M = 11.55 SD = 2.36
Building	M = 7.10 SD = .65	M = 7.51 SD = 2.63	M = 7.84 SD = 2.35	M = 7.32 SD = 2.48	M = 7.44 SD = 2.02

Table D-3

Distance Traversed (feet) as a Function of Training Group, Map Usage, and Gender: Means and Standard Deviations

Training Group	Map		No Map		Entire Population
	Female	Male	Female	Male	
VE	M = 1872 SD = 160	M = 1893 SD = 516	M = 1883 SD = 283	M = 1916 SD = 100	M = 1891 SD = 284
Symbolic	M = 1955 SD = 618	M = 1895 SD = 414	M = 1979 SD = 548	M = 2098 SD = 422	M = 1982 SD = 472
Building	M = 1689 SD = 132	M = 1659 SD = 147	M = 1707 SD = 112	M = 1699 SD = 206	M = 1688 SD = 132

Appendix E. Configuration Learning Test Performance Means and Standard Deviations

Table E-1

Projective Convergence Test Consistency (perimeter in feet) as a Function of Training Group, Map Usage and Gender: Means and Standard Deviations

Training Group	Map		No Map		Entire Population
	Female	Male	Female	Male	
VE	M = 252.32 SD = 130.06	M = 68.48 SD = 29.07	M = 200.4 SD = 83.87	M = 161.34 SD = 99.72	M = 170.64 SD = 109.87
Symbolic	M = 222.40 SD = 126.05	M = 108.08 SD = 67.12	M = 201.92 SD = 114.06	M = 188.88 SD = 165.01	M = 180.32 SD = 121.44
Building	M = 150.24 SD = 106.21	M = 180.48 SD = 151.44	M = 152.00 SD = 88.67	M = 146.88 SD = 100.34	M = 157.41 SD = 105.68

Table E-2

Projective Convergence Test Accuracy (deviation in feet) as a Function of Training Group, Map Usage and Gender: Means and Standard Deviations

Training Group	Map		No Map		Entire Population
	Female	Male	Female	Male	
VE	M = 101.68 SD = 28.01	M = 49.28 SD = 24.44	M = 83.44 SD = 37.88	M = 79.28 SD = 40.01	M = 78.42 SD = 36.09
Symbolic	M = 104.96 SD = 49.51	M = 89.12 SD = 37.65	M = 92.4 SD = 28.20	M = 79.60 SD = 58.99	M = 91.52 SD = 42.44
Building	M = 103.44 SD = 32.93	M = 82.16 SD = 24.36	M = 87.04 SD = 31.94	M = 83.60 SD = 38.32	M = 89.06 SD = 30.87

Table E-3

Projective Convergence Test Average Distance Error (in feet) as a Function of Training Group, Map Usage and Gender: Means and Standard Deviations

Training Group	Map		No Map		Entire Population
	Female	Male	Female	Male	
VE	M = 76.34 SD = 22.29	M = 32.40 SD = 14.39	M = 57.36 SD = 22.23	M = 54.82 SD = 18.67	M = 55.23 SD = 24.11
Symbolic	M = 55.14 SD = 28.85	M = 38.93 SD = 10.54	M = 54.85 SD = 14.06	M = 50.67 SD = 27.44	M = 49.90 SD = 21.08
Building	M = 72.24 SD = 19.92	M = 51.55 SD = 8.56	M = 62.08 SD = 25.46	M = 47.92 SD = 18.02	M = 58.45 SD = 19.98

Table E-4

Projective Convergence Test Average Miss Distance (in feet) as a Function of Training Group, Map Usage and Gender: Means and Standard Deviations

Training Group	Map		No Map		Entire Population
	Female	Male	Female	Male	
VE	M = 118.94 SD=20.04	M = 49.81 SD = 25.55	M = 88.05 SD = 30.14	M = 88.58 SD = 39.52	M = 86.34 SD = 37.08
Symbolic	M = 97.39 SD=43.31	M = 90.08 SD = 36.00	M = 102.56 SD = 19.13	M = 81.89 SD = 52.93	M = 92.98 SD = 37.40
Building	M = 96.15 SD = 27.16	M = 81.65 SD = 25.69	M = 93.12 SD = 32.71	M = 82.64 SD = 34.87	M = 88.39 SD = 28.60

Table E-5

Building Exit Test Exit Time (min) as a Function of Training Group, Map Usage and Gender: Means and Standard Deviations

Training Group	Map		No Map		Entire Population
	Female	Male	Female	Male	
VE	M = 1.13 SD = 0.50	M = 0.91 SD = 0.31	M = 0.89 SD = 0.12	M = 0.76 SD = 0.17	M = 0.92 SD = 0.32
Symbolic	M = 0.92 SD = 0.18	M = 0.92 SD = 0.18	M = 1.15 SD = 0.25	M = 0.72 SD = 0.18	M = 0.93 SD = 0.24
Building	M = 1.07 SD = 0.26	M = 0.97 SD = 0.41	M = 1.16 SD = 0.41	M = 0.75 SD = 0.11	M = 0.99 SD = 0.33

Table E-6

Building Exit Test Distance (feet) Traversed as a Function of Training Group, Map Usage and Gender: Means and Standard Deviations

Training Group	Map		No Map		Entire Population
	Female	Male	Female	Male	
VE	M = 314.63 SD = 119.78	M = 280.25 SD = 78.38	M = 255.75 SD = 67.72	M = 239.55 SD = 71.44	M = 272.55 SD = 84.83
Symbolic	M = 270.12 SD = 96.82	M = 279.77 SD = 62.95	M = 323.78 SD = 70.59	M = 248.33 SD = 131.22	M = 280.5 SD = 73.00
Building	M = 259.23 SD = 36.08	M = 248.83 SD = 131.22	M = 326.97 SD = 97.64	M = 242.48 SD = 32.03	M = 269.39 SD = 85.57